Nitrogen cycling in an alfalfa-bromegrass sward

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Research was carried out to follow the fate of N in an alfalfa-bromegrass pasture at the Saskatchewan Irrigation Development Center at Outlook. Swards of monocropped alfalfa and bromegrass and intercropped alfalfa-bromegrass were established to study the transfer of N between these two species. The swards, seeded in May 1990, were irrigated and managed as hay crops during three consecutive years.

The movement of N between the various sources and sinks of N in the intercropped alfalfa-bromegrass system is summarized in Fig. 1. Estimates were averaged over the last two years of the study once the swards were fully established. Nitrogen removed by hay harvest was 206 and 37 kg ha^{-1} $yr^{-1}$for alfalfa and bromegrass, respectively. The N returned to the soil by alfalfa and bromegrass in fallen leaves amounted, respectively, to 16 and 4 kg ha^{-1} yr^{-1}. N losses during harvest were 18 and 9 kg of N ha^{-1} yr^{-1} for the alfalfa and bromegrass, respectively. The average annual accumulation of N in stubble+roots (0-30 cm depth) amounted to 136 kg ha^{-1} or alfalfa and 95 kg ha^{-1} for bromegrass.

Sixty-three percent of N accumulated by intercropped bromegrass and 40% of the N accumulated by intercropped alfalfa was allocated to the stubble+roots.

Most N-cycling studies in swards report measurements on forage only. However, alfalfa has an effect on the dry matter production and N accumulation in forage+stubble+roots of the intercropped bromegrass. Whereas no significant increase in the bromegrass N accumulation due to the associated alfalfa was observed on bromegrass forage or on stubble+roots to 30 cm depth, a significant N benefit from alfalfa was detected when the N accumulation in forage of bromegrass was combined with the increase in N accumulation in the stubble+roots.

The amount of N_2 fixed accumulated in the forage of intercropped alfalfa averaged 195 kg N ha^{-1} yr^{-1} and fixed-N accumulated in the stubble+roots to 30 cm depth averaged 80 kg N ha^{-1} yr^{-1}. The contribution of N from N_2 fixation to the growth of the intercropped grass and their residual effect on succeeding crops is greatly underestimated if the estimate does not consider the N accumulation in stubble and roots.

Eighteen kg N ha^{-1} yr^{-1} of transferred N was accumulated in bromegrass forage, of which 6 and 12 kg N ha^{-1} yr^{-1} was derived from the soil and N_2 fixation, respectively.

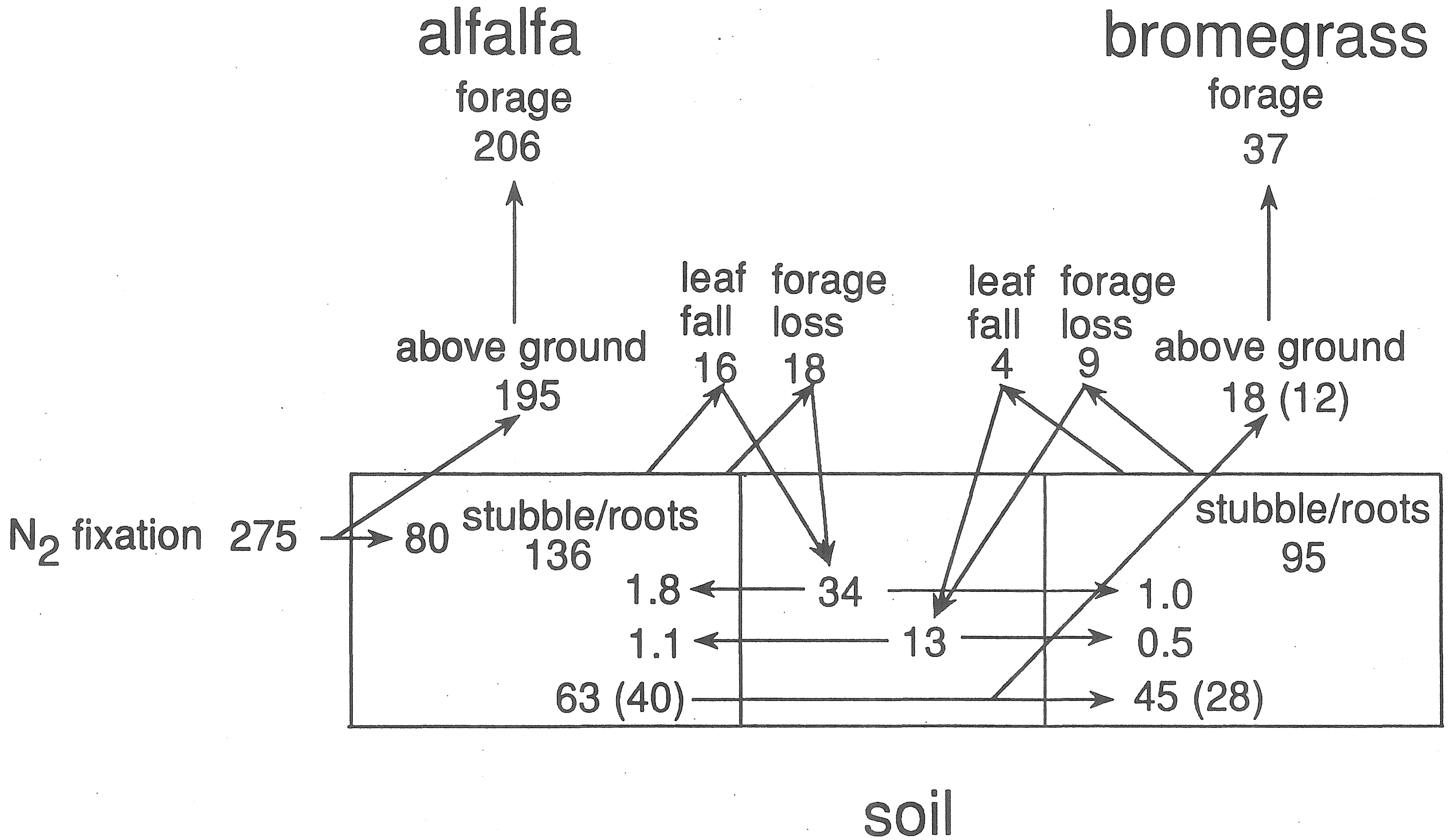

Fig. 1. Cycling of nitrogen in an alfalfa-bromegrass sward. The values represent the annual flow of N following the establishment of the sward.

Inclusion of the non-removable plant parts (stubble and roots) in the estimates of N in bromegrass derived from alfalfa increased the amounts of N transferred to 45 kg N ha^{-1} yr^{-1}. These amounts indicate that on average 71% of the transferred N was accumulated in the stubble and roots of bromegrass. From this amount of transferred N, approximately 23 kg ha^{-1} yr^{-1} was derived from the soil-N pool and 40 kg ha^{-1} yr^{-1} was derived from N_2 fixation by alfalfa. These estimates of N transfer from alfalfa to bromegrass, illustrate the importance of considering all plant parts with their corresponding N yields when evaluating N transfer in perennial swards.

In general, symbiotic N_2 fixation is increased and N transfer to associated crops is enhanced and easier to detect under low available soil-N than when soil mineral N is plentiful. Therefore, no N-fertilizer was applied during the three years of the field study and a small accumulation of N by bromegrass was observed. The amount of N transferred from bromegrass to alfalfa was also small. It is likely that the limited accumulation of N by bromegrass due to low N also reduced the transfer of N from bromegrass to alfalfa since bromegrass plants were a small source of N for transfer. Therefore, a larger transfer of N from bromegrass to alfalfa might occur if the growth and N accumulation of bromegrass was enhanced through N fertilization or by growing these two crops on soils with a high N-fertility level.

Available soil-N to 15 cm depth decreased from 40 $\mu g\ g^{-1}$ of soil before seeding to less than 8 $\mu g\ g^{-1}$ of soil (15.6 kg N ha^{-1}) by the fall of the establishment year, and remained below 11 $\mu g\ g^{-1}$ of soil for both species and cropping systems throughout the duration of the experiment. No agronomically relevant differences were present among treatments for available N levels in the 0-60 cm depth. This indicated that available soil N was readily incorporated in plants and/or immobilized by microorganisms following establishment of the swards. In addition, these results indicated that both alfalfa and bromegrass deplete available soil N to similar low levels.

The competitive ability of alfalfa and bromegrass for N sources was estimated in the field by their forage ^{15}N-accumulation from ^{15}N-labelled soil-N and ^{15}N-labelled residues. No significant differences were found for the ^{15}N-accumulation of monocropped alfalfa or monocropped bromegrass and the ^{15}N-accumulation of these intercropped species when adjusted for spacing. These results support the hypothesis that alfalfa is a strong competitor for available N when intercropped with bromegrass.

The partitioning of available N derived from ^{15}N-labelled leaf fall or hay loss residues was evaluated by the forage ^{15}N-accumulation of alfalfa and bromegrass under field conditions. The amount of N accumulated by intercropped alfalfa (1 plus 0.8 kg N ha^{-1} yr^{-1}) was almost double the amount of N accumulated by the intercropped bromegrass (0.7 plus 0.4 kg N ha^{-1} yr^{-1}), indicating that alfalfa could out competed bromegrass for available N derived from plant residues. This agrees with previous findings that legumes may increase the supply of available N in the root medium, but may also compete with the intercropped grass for this N. These results contradict literature reports of limited competition for N between intercropped N_2-fixing legumes and soil-N dependent grasses.

Studies demonstrated that N can be transferred from grass to legume, even though growth of the grass is limited by an inadequate supply of N. In the field, N released from one plant through fallen leaves or hay loss was taken up by intercropped plants of the same species or a different species. Nitrogen from plant residues was transferred between species (from alfalfa to bromegrass and *vice versa*), as well as within species (from alfalfa to alfalfa and from bromegrass to bromegrass).

The occurrence of N transfer from bromegrass to alfalfa implies that in order to calculate the net N benefit of a N_2-fixing species to an intercropped grass, the amount of N transferred from the grass to the legume should be subtracted from the N transfer in the opposite direction. Therefore, estimates of fixed-N transferred based on ^{15}N isotope dilution would not provide information on the total flow of N from legumes to intercropped grasses.

A good agreement was observed between the amounts of transferred N estimated by the N-difference and the ^{15}N-isotope dilution methods in the second and third year of this research. This indicates that the increase in bromegrass-N suggested by the isotope dilution is confirmed by a corresponding increase in the amount of N accumulated by the net beneficiary of the transfer of N. In addition, the good agreement in the estimates using the two approaches suggests that the amount of soil-N transferred from alfalfa to bromegrass was similar to the amount transferred in the opposite direction, or else, that the amount of N transferred from bromegrass to alfalfa was not large enough to significantly affect the estimate of the net N transfer between the two species.

Field estimates indicated that the average estimates of N in bromegrass derived from N_2 fixation by alfalfa increased from 13% in the first year to 32% and 34% in the second and third year, respectively. This increase in N transfer is likely caused by two reasons. Firstly, an increase in N_2 fixation and, consequently, the source of N for transfer from alfalfa to bromegrass increased in this period. Secondly, a larger demand for N occurred in the second and third year due to the increased age and size of plants. A more intense competition for N between plants is expected, and the effect of maturity, senescence and death of plants should contribute more to N transfer following establishment. Therefore, it is unlikely that the net N transfer between perennial species during the life of the sward will be accurately estimated by short-term N transfer measurements on young stands.

The above ground and below ground N yields and the amount of N_2 fixed in the second year were similar to those in the third year indicating that the N cycling in the alfalfa-bromegrass mixture likely reached equilibrium. In addition, the average crop removal of N in the grass-legume cropping system was 206 kg N ha^{-1} yr^{-1} whereas 275 kg N ha^{-1} $yr^{-1}$was derived from N_2 fixation. The amount of N lost through leaching and denitrification was considered to be low because of the low amounts of available N in the 0-120 cm soil profile. Additional N input through wet or dry deposition also is considered to be marginal at this site. Therefore, there was an increase in the total soil N pool of ≈ 70 kgNha^{-1} yr^{-1} in this established alfalfa-bromegrass mixture.

Because the carbon to nitrogen ratio (C/N) of organic matter equilibrates around 12, the C content in the soil would increase be approximately 720 kg year, or the total soil organic matter can increase by ≈ 1400 kg per year in a non-N limiting pasture.